THE EFFECT OF DRAFT TUBE ON THE PERFORMANCE OF A SPOUTED BED FOR RICE HUSK COMBUSTION

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ABSTRACT

The production of paddy in Malaysia is around 2,2 million metric tonnes which rice husk represents 20% of the weight. Rice mills usually disposed the rice husk through open burning. With the cost increment of fossilized fuel, rice husk would have the potential to be a cheap source of renewable energy. In addition, rice husk ashes also contained a high content of silica, an important raw material for industries. Previous studies on the fluidized bed technology have shown its potential in waste disposal and energy recovery from biomass. Spouted bed offers several advantages in comparison with the bubbling fluidized bed such as a better solid mixing and low-pressure drop to maintain the bed fluidization. With the low bulk density of rice husk (100 kgm^{-3}) compared to the inert bed material and having a high content of volatile matter (64%), most of rice husk burn in the freeboard region. It is important to burn the husk in the bed to maintain the bed temperature. Mixing study conducted has shown the preferred sand size in the range of 600-850 μm with the operating bed height of 1-1.5 D_c. Air velocity of 2-3 U_{ms} was not feasible due to the nature of the husk. With conventional spouted bed, circulation of particles slowed down at the dense phase of the bed. With a draft tube, it was seen to improve circulation and burning. This paper reports the difference of rice husk combustion with and without the draft tube in a spouted bed combustor.

Keywords: Rice husk; combustion; spouted bed; draft tube

INTRODUCTION

With the increasing cost of fossil fuel and the vast depletion of these fuels, there is an urgent need to find a suitable renewable energy source. Biomass does have the potential to be the energy source as it could be replenished and is environmental friendly. One of this biomass is rice husk. The annual production of rice husk in Malaysia is about 2.2 million metric ton annually and rice husk, which is about 20% of the total weight, is available in abundance. The current practice of disposal such as open burning is environmental hazards to the surroundings. Thus far, only a few mills have the facility to burn the rice husk but then, the burning of the husk is still incomplete.

The abrasive nature of silicon dioxide in the rice husk ash has frustrated attempts for an advanced energy conversion. The low bulk density of the rice husk (100 kgm^{-3}) has made the transportation of the husk to a utilization site situated far away from the mill not economical. Thus, the husk could be converted to a useful form of energy to meet the thermal and mechanical energy requirements of the mills.

Spouted bed has been successfully used in the industries especially for drying purposes [1] since Mathur and Gishler in 1955. The systematic cyclic pattern of movement for the bed particles has made the system to possess a good mixing. The advancement of spouted bed technology has made it possible to be applied in the field of combustion, which was initially conducted by Khoshnoodi and Weinberg [2]. In addition, Arbib and Levy [3] have documented combustion of low heating fuel with spouted bed.

Previous studies on the combustion of rice husk using bubbling fluidized bed had been documented [4, 5]. However, spouted bed does offer many advantages over fluidized bed and fixed bed especially in terms of design [6]. With these advantages, spouted bed has the potential to be used for the combustion of rice husk in Malaysia.

The objective of this study is to determine the feasibility of spouted bed for the combustion of rice husk with a small column dimension. Previous combustion of rice husk with spouted bed has been conducted with a big column diameter of 15.2-cm [7] but none of such studies has been carried out using a smaller column dimension. In addition, spouted bed combustion using draft tube for low caloric solid fuel had also not been documented.

EXPERIMENTAL STUDIES

The experimental rig for the spouted bed has been described in Rozainee *et al.* [8]. The rig consists of a cone with a 60°-cone angle, the internal diameter of the combustor of 80 mm and the combustor height of 800 mm. Between the cone and the combustor body section, a piece of cylinder glass measuring 80 mm in diameter and 210 mm height was connected to view the bed behaviour during the cold and the hot run. The inlet orifice has an internal diameter of 8 mm. Air was supplied by a compressor and was passed through an air filter to remove the moisture. Pressure drop was determined by means of water manometer.

Commercial silica sand granules having in the size range of 600-850μm (d_p = 0.67mm) was used as the bed materials. The bulk and particle density of the silica sand was 1460 kgm^{-3} and 2430 kgm^{-3} respectively. The optimum parameters for the spouted bed have been determined to be at 1 Dc bed height with the spouting velocities of 2-3 Ums with the cold run [8]. The proximate and ultimate analysis of the rice husk sample used in this study is as Table 1 [8].

Table 1: Rice husk analysis.

Proximate Analysis	**Weight %**
Moisture	10.09
Volatile matters	64.13
Fixed carbon	11.06
Ash	14.72
Gross Caloric Value (MJ/kg)	13.31
Ultimate Analysis	
C	37.75
H	4.97
O	41.93
N	0.63

METHODOLOGY

The circulation of solids in the bed was investigated using a 'saga' seed with a mean diameter of 10 mm and particle density of 1220 kgm^{-3}. The seed would be dropped into the bed with its movement being tracked. The particle velocity in the annulus was determined as described by Ji *et al.* [9]. The time taken by a particle at the annulus for a fixed distance of 2 cm at the glass section during the cold run was recorded.

One thermocouple was located at the cone region for sand temperature, one at the freeboard and one at the cyclone outlet. The subsequent freeboard temperature was measured at 30cm away from the surface of the bed. The sand temperature was determined with a thermocouple inserted at a vertical direction from the cone region. A draft tube of 60 mm diameter and 100 mm length was used for the comparison of rice husk combustion with and without draft tube using the spouted bed. Determination of minimum spouting velocity (Ums) was by plotting the inlet velocity versus the pressure drop to locate the point of which a sudden decrease in pressure drop against the inlet velocity occurred.

For the combustion of rice husk in a spouted bed, the bed was initially preheated to a temperature of 700-750°C by using LPG at equivalence ration of 1. The desired combustion temperature for rice husk was around 700-750°C [10]. Once the bed temperature was stable, rice husk would then be fed through the top of the bed using a screw conveyor, which is connected to a variable motor. Temperature readings for the cone section, the sand, the freeboard and the temperature inside the cyclone were recorded very minute

RESULTS AND DISCUSSION

Cold Run With The Spouted Bed

The results of the cold run in spouted bed for both with and without the draft tube is given in Table 2. With the draft tube the residence time of the saga seed increased to 3 times when compared to the normal spouted bed. This was because the draft tube acted a barrier for the spout and the annulus region and thus prevented a "short circuit" movement of the particle. The range of residence time with the draft tube was between 16-33 seconds. This was due to the movement of the saga seed whether if falls outside the draft tube circumference and thus would move in a bigger cyclic motion in comparison to the falling position into the area inside the draft tube and thus would still be affected by the "short circuit" movement. The presence of draft tube has enhanced the circulation of particles, as the annulus velocity with draft tube was around 1.16 times higher than the normal spouted bed. This is similar to the findings by Muir *et al.* [11], which further states that draft tube would enhance smooth solids flow and provide a wider stable operating range.

Table 2: Residence time and annulus velocity in the spouted bed at 1.5 Dc bed height.

Run	Without draft tube		With draft tube	
	Residence time (s)	Annulus velocity (cms^{-1})	Residence time (s)	Annulus velocity (cms^{-1})
1	8	0.40	18	0.33
2	11	0.29	23	0.33
3	4	0.29	16	0.33
4	8	0.29	33	-
5	5	0.33	29	-
6	11	-	31	-
7	5	-	-	-
8	8	-	-	-
Average	7.5	0.289	25	0.33
Ums (ms^{-1})	0.19 – 0.25		0.18 – 0.28	

Spouted Bed Without Draft Tube

The hot run of the conventional spouted bed without draft tube was conducted for rice husk. From Figure 1, the combustion of rice husk could not be sustained. Once the LPG had been switched off, the bed temperature continues to drop tremendously. This suggests that spouted bed combustion of rice husk with small column diameter is not advisable due to bad mixing of the bed particle at high temperatures. . The temperature at the freeboard and cyclone suggest that the combustion of volatile was present. Stratification was also evident at the neck before the cone section and this phenomenon was absent during cold run.

Spouted Bed With Draft Tube

The hot run of the spouted bed fitted with a specified draft tube dimension produced good results on the continuation combustion of rice husk as shown in Figure 2. Once the LPG had been switched off, the bed temperature dropped until around 600°C. This was due to the heat absorbed by the husk for combustion. The continuation of combustion showed there was improvement in the particle circulation. Stratification at the bed also did not occur. The char of the husk could also now be burnt in the bed to stabilize the bed temperature thus suggesting a proper mixing of bed particles with the char.

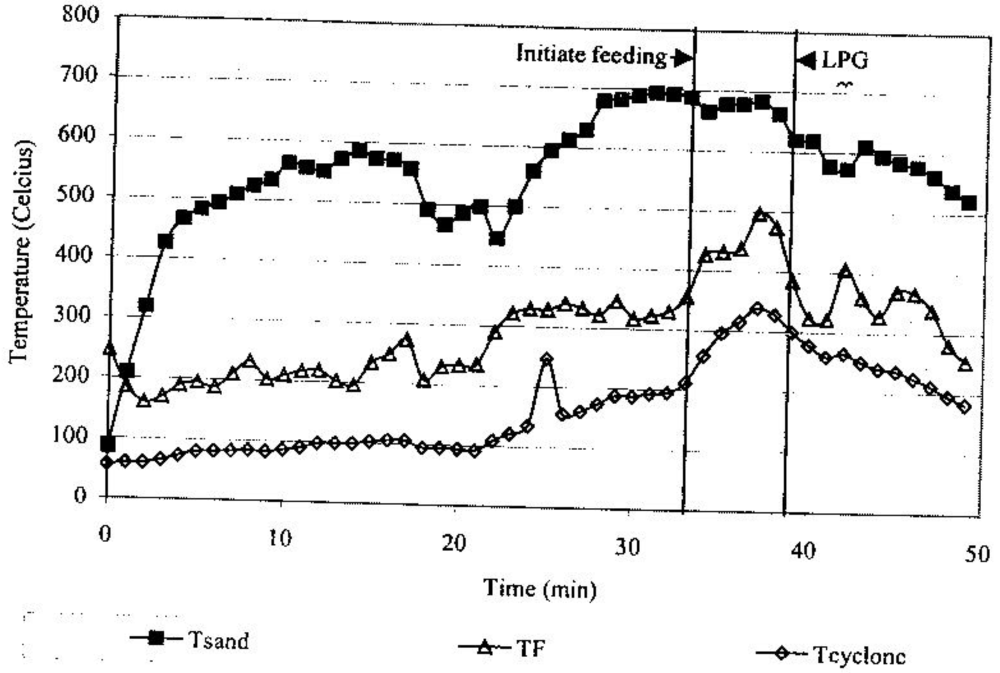

Figure 1: Spouted bed combustion of rice husk without the draft tube (feeding of rice husk at 29 gm/minute).

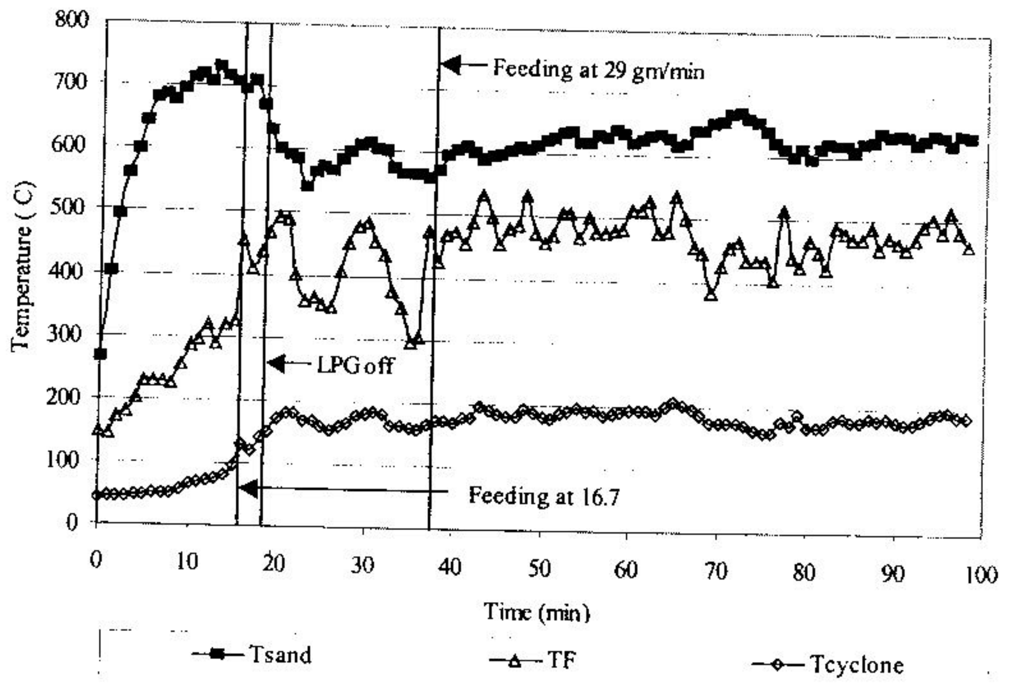

Figure 2: Combustion of rice husk with spouted bed fitted with a draft tube (initial feeding of rice husk was at 16.7 gm/minute. The rice husk feeding was then maintained at 29.0 gm/minute; combustion was conducted with 20% excess air).

CONCLUSIONS

The inclusion of a draft tube has managed to sustain the combustion of rice husk in a small column spouted bed using sand as the bed material. This was due to the better circulation of bed particles and thus indirectly improved the mixing characteristics. Stratification did not occur during the cold run but was evident during the hot run. This gives rise to a poor mixing for conventional spouted bed without the draft tube.

NOTATIONS

Ums = Minimum spouting velocity (ms^{-1})
Dc = Column diameter (m)
Tsand = Sand temperature (°C)
TF = Freeboard temperature (°C)
Tcyclone = Cyclone temperature (°C)

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